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Soil Fertility Dynamics of *Hibiscus surattensis* L. as Influenced by Bioinoculant Application Grown in Different Soil

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Abstract

Bioinoculants are introduced into the soil or rhizosphere to facilitate nutrient cycling, mineral solubilization, and phytohormone production that contribute to soil fertility and plant performance. Despite its ecological importance, there is a lack of research examining how bioinoculant application influences the soil chemical properties associated with its growth across different soil types. Hence, this study was conducted to determine the influenced of bioinoculants application to soil fertility dynamics of *Hibiscus surattensis* grown in different soil types. The study was carried out using a 2 x 8 Factorial Randomized Complete Block Design (RCBD). Results indicated that soil pH decreased from the initial to the final measurement, with the control showing the highest pH. The application of Mykoplus resulted in significantly higher levels of organic matter (OM), nitrogen, and exchangeable potassium (K) compared to other treatments, with the highest effect observed in neutral soil. An interaction effect was observed for available phosphorus, which was significantly influenced by both soil type and bioinoculant application, with the highest levels recorded at 100% of the recommended fertilizer rate. To improve soil fertility dynamics, it is recommended to apply Mykoplus as a bioinoculant and to conduct similar studies on different crops to validate these results.

Keywords: Bioinoculants, Mykoplus, Organic matter, Soil analysis, Soil fertility

Research article
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INTRODUCTION

The use of bioinoculants in agricultural systems has been increasingly recognized as a sustainable strategy for improving soil chemical properties, enhancing nutrient availability, and promoting plant growth (Orozco-Mosqueda et al., 2021). Bioinoculants are introduced into the soil or rhizosphere to facilitate nutrient cycling, mineral solubilization, phytohormone production, and other key processes that contribute to soil fertility and plant performance.

These microorganisms interact with soil chemical dynamics by altering pH, increasing the availability of essential nutrients such as nitrogen (N), phosphorus (P), and potassium (K), and enhancing organic matter turnover, thereby improving the overall soil nutrient status (Orozco-Mosqueda et al., 2021).

Soil chemical properties including soil pH, organic carbon, available nitrogen, phosphorus, and other exchangeable nutrients are critical determinants of plant growth and crop productivity. Changes in these properties are often mediated by microbial activity, mineral transformations, and interactions between microbes and plant roots. Studies have shown that inoculation with bioinoculants can influence soil nutrient dynamics by increasing available N and P through microbial fixation and solubilization pathways, and by enhancing enzyme activities that drive nutrient release and transformation in the rhizosphere (Chen et al., 2021). For example, the application of different types of microbial inoculants significantly increased available soil nitrogen and altered bacterial community composition in high-phosphorus soils, demonstrating the potential of bioinoculants to modify key soil chemical parameters linked to plant nutrition and soil fertility. Moreover, microbial inoculation has been found to modify soil organic matter content, soil pH, and available nutrient stocks, often with consequent effects on plant performance and resilience to stress. In studies involving a range of crop species, bioinoculants enhanced soil organic carbon and available phosphorus, while also stimulating soil enzymatic activities that are essential for nutrient mineralization and soil fertility enhancement (He et al., 2024). However, the influence of bioinoculants on soil chemical properties can vary depending on soil type, such as differences in texture, initial nutrient status, and native microbial communities. Such variability underscores the importance of evaluating bioinoculant effects across diverse soil environments.

Hibiscus surattensis is cultivated in various regions across the Philippines, including Metro Manila, the Visayas, and Mindanao. While comprehensive data on cultivation areas and production levels are limited, its presence in local markets and online platforms indicates a growing interest in its cultivation and use (Agriculture.com.ph, 2017). Despite its ecological importance and frequent use in agroecosystems, there is a lack of peer-reviewed research examining how bioinoculant application influences the soil chemical properties associated with its growth across different soil types. Understanding these interactions is essential for developing sustainable soil management practices and optimizing nutrient supply for this species. Hence, this study was conducted to determine the influence of bioinoculants' application to soil fertility dynamics of *Hibiscus surattensis* grown in different soil types.

MATERIALS and METHODS

Experimental site

The experiment was carried out at the Soil Science protected structure, Department of Soil Science, College of Agriculture and Food Science, Visayas State University, Visca, Baybay City, Leyte

Soil sample collection

A collection of soils for the planting medium of *Hibiscus surattensis* was done within the VSU campus. Acidic soils were collected at the Department of Animal Science, while the neutral soils were collected at the Department of Agronomy.

Soil Analysis

A minimum of 20 small samples were taken randomly from each field to obtain a representative soil sample. The composite sample was air-dried, pulverized using a wooden mallet, and sieved through a 2-mm wire mesh to obtain the fine earth for the analysis of Soil pH, Total N, Available P, and Exchangeable K. For organic matter determination, sufficient soil samples were further pulverized and let to pass through a 0.425-mm wire mesh, and this was conducted before the conduct of the potting experiment.

Treatment preparations

Commercial bioinoculants were used, and only standardized and certified bioinoculant products from the University of the Philippines, Los Baños Biotechnology, were utilized to ensure consistency. Each bioinoculant was prepared according to the manufacturer's standard concentration and application guidelines. Mykovam was applied at a rate of 5 g per plant, as recommended by the Department of Biotechnology, University of the Philippines; Bio-N was prepared by dissolving 200 g in 16 L of water and applied at 150 mL per plant; and Mykoplus was applied at a rate of 5 g per plant.

Seedling Preparation and Transplanting

Healthy and uniform stem cuttings of *Hibiscus surattensis* were selected from mature plants. Cuttings were trimmed to a length of 15-20 cm with at least two nodes per cutting. Cuttings were pre-rooted in a seedling tray containing a 1:1:1 mixture ratio of soil, carbonized rice hull, and vermicast for two weeks before transplanting to ensure root development. The pre-rooted cuttings were carefully transplanted into the prepared pots at a uniform depth. The pots consisted of 6 x 6 x 10-inch polyethylene bags filled with the different air-dried soil types (acidic and neutral soil).

Preparation of Soil Potting Media

Composite soil surface (0-20cm) soil samples were collected from each area of interest with the use of a shovel. The collected sub-samples were thoroughly mixed, put in a sack, and air-dried for pulverizing and sieving for use in the experiment.

Experimental design and treatments

The study was carried out using a 2 x 8 Factorial Randomized Complete Block Design (RCBD). Factor A consisted of two (2) treatments corresponding to the different soil types, namely as follows: A1– Acidic Soil and A2 – Neutral Soil. Factor B was composed of eight (8) treatments corresponding to different bioinoculants follows: B0 - Control (water only), B1 – 100% Recommended rate of fertilizer (RR) B2 – Mykovam, B3 – Mykovam + 50% RR, B4 – BIO – N, B5 – BIO – N + 50% RR, B6 – Mykoplus, B7 – Mykoplus + 50% RR. Each treatment was replicated 4 times.

Water Management

During the first few days after transplanting, the plants were watered regularly to speed up recovery from transplanting shock. Thereafter, watering was done depending on the moisture condition of the soil. Sprinklers with a 6-liter capacity were used in this study.

Data Gathered

Soil Parameters

An initial (pre-treatment) and final (post-treatment) analysis of soil pH, Organic Matter, Total Nitrogen, Available Phosphorus, and Exchangeable Bases K status was performed to assess the impact of the various bioinoculants on the properties of neutral and acidic soils, and the soil sample was sent to SRA Environmental Laboratory Services – Bacolod for chemical analysis.

Statistical Analysis

Data was statistically analyzed using the STAR software. The presence of significant differences among treatments was determined using Analysis of Variance (ANOVA) arranged in a factorial RCBD. Comparison of treatment means was done using Tukey's Honestly Significant Difference (HSD) Test at 5% level of significance.

RESULTS and DISCUSSION

Soil pH

Figure 1 and 2 presents the soil pH of *H. surattensis* grown under different soil types and bioinoculant applications. The results showed significant differences in soil pH among soil types and bioinoculant treatments. A general decrease in pH was observed from the initial to the final sampling period. Among soil types, the highest mean pH was recorded in neutral soil (5.60), whereas the lowest pH was observed in acidic soil (4.52). Regarding bioinoculant applications, plants in the control treatment had the highest mean soil pH (5.43), which was comparable to most treatments, except for Mykoplus + 50% RR and Mykovam + 50% RR, which recorded lower pH values of 4.89 and 4.83, respectively. The lowest soil pH was observed in plants treated with 100% RR, with a mean value of 4.57. No interaction effect was observed in the ANOVA. These findings are supported by research showing that microbial inoculants and bioinoculants can alter soil physicochemical properties, including soil pH, through biological processes such as organic acid production, nutrient solubilization, and changes in microbial activity (Maitra, 2021). Studies have also demonstrated that the application of plant growth-promoting rhizobacteria (PGPR) and related microbial amendments can influence soil properties and nutrient cycling factors that are intimately linked with soil pH and overall soil health (Jing et al., 2025). Bioinoculant applications can significantly affect soil pH by altering microbial populations and their metabolic processes, such as the production of organic acids (Hernandez et al., 2020). For example, plant growth-promoting rhizobacteria (PGPR) have been reported to lower soil pH by secreting organic acids, thereby enhancing nutrient availability and modifying the soil environment for better plant growth (Dey et al., 2021). Furthermore, similar studies have also shown that soil pH decreases with increased microbial activity in soils treated with bioinoculants compared to untreated controls, emphasizing the role of microbial inoculants in managing soil health (Singh et al., 2017).

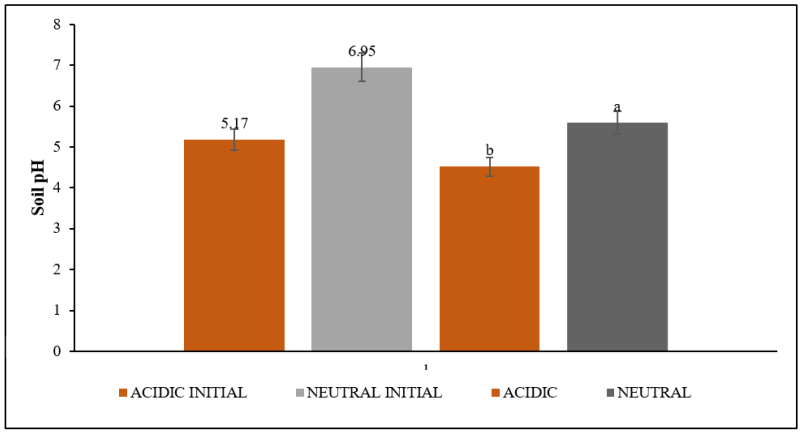


Figure 1. Soil pH of *Hibiscus surattensis* grown in different soil types. Means followed by the same letter within each soil type are not significantly different at $p \leq 0.05$ based on Tukey's HSD test. Error bars represent ± standard error of the mean

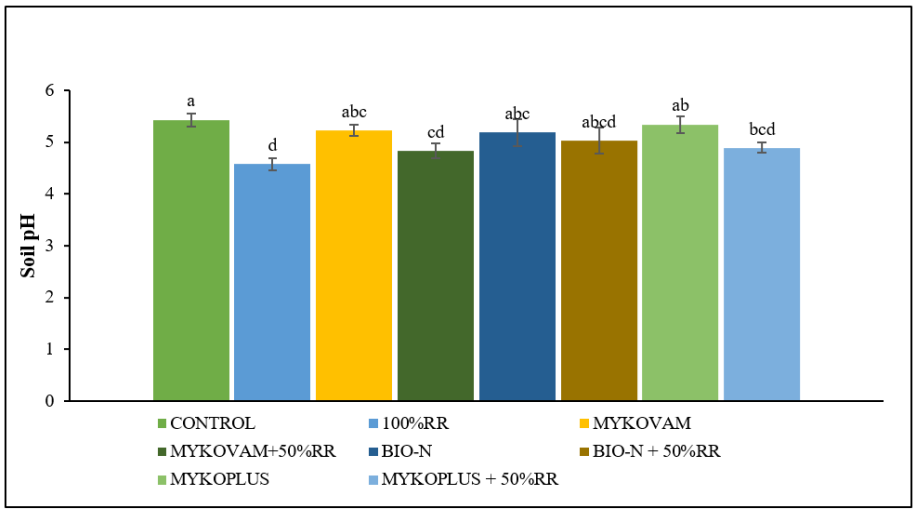


Figure 2. Soil pH of *Hibiscus surattensis* applied with different bioinoculants. Means followed by the same letter within each soil type are not significantly different at $p \leq 0.05$ based on Tukey's HSD test. Error bars represent ± standard error of the mean

Soil Organic Matter (%)

Soil organic matter (SOM) plays a critical role in plant growth and soil productivity by improving soil physical and chemical properties. It enhances soil structure and aggregation, thereby increasing water-holding capacity, aeration, and root penetration. The SOM of soil planted with *H. surattensis* and applied with different bioinoculants is presented in Figure 3 & 4. Results show that both soil types and bioinoculant application significantly influenced soil organic matter, and that SOM increased from the initial to the final analysis. The highest SOM was observed in plants grown in neutral soil, with a mean of 1.48%, and the lowest was recorded in acidic soil, with a mean of 0.65%. Furthermore, the highest SOM was recorded in plants applied with Mykoplus, with a mean value of 1.32%, comparable to Mykoplus + 50% RR, with a mean value of 1.27%. The lowest SOM was observed in the control, with a mean value of 0.93, which was comparable to other bioinoculants except Mykoplus and Mykoplus + 50%RR. No interaction effect was recorded in ANOVA.

These findings are consistent with peer-reviewed evidence showing that biofertilizers and plant-growth-promoting rhizobacteria (PGPR) can increase soil organic carbon and organic matter by enhancing microbial activity and nutrient cycling (Just 2024; Singh et al 2022). Research has shown that the application of biofertilizers significantly increased soil organic carbon concentrations across multiple studies, supporting the role of microbial inoculants in improving soil quality and organic matter content relative to uninoculated controls (Just 2024). Additionally, studies on PGPR treatments have documented increases in soil organic carbon and total nitrogen following microbial applications, indicating that microbial inoculants can enhance soil organic matter by improving nutrient transformations and soil biochemical processes (Singh et al 2022). These mechanisms help explain the observed higher SOM values in treatments with Mykoplus and Mykoplus + 50%RR compared to controls

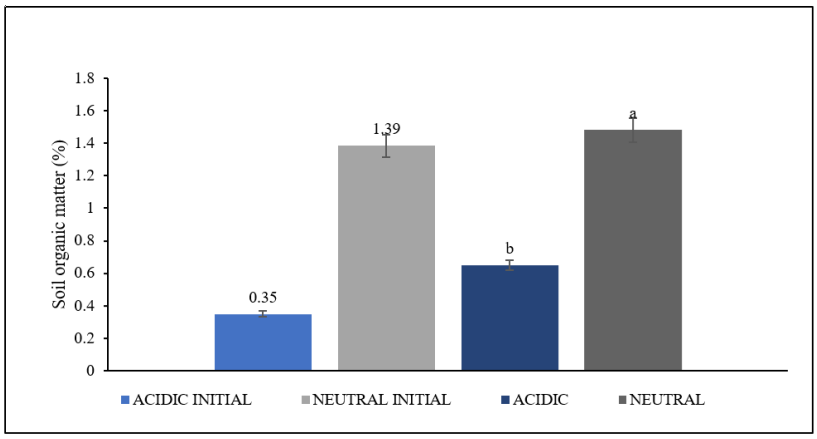


Figure 3. Soil organic matter (%) of *Hibiscus surattensis* grown in different soil types. Means followed by the same letter within each soil type are not significantly different at $p \leq 0.05$ based on Tukey's HSD test. Error bars represent ± standard error of the mean

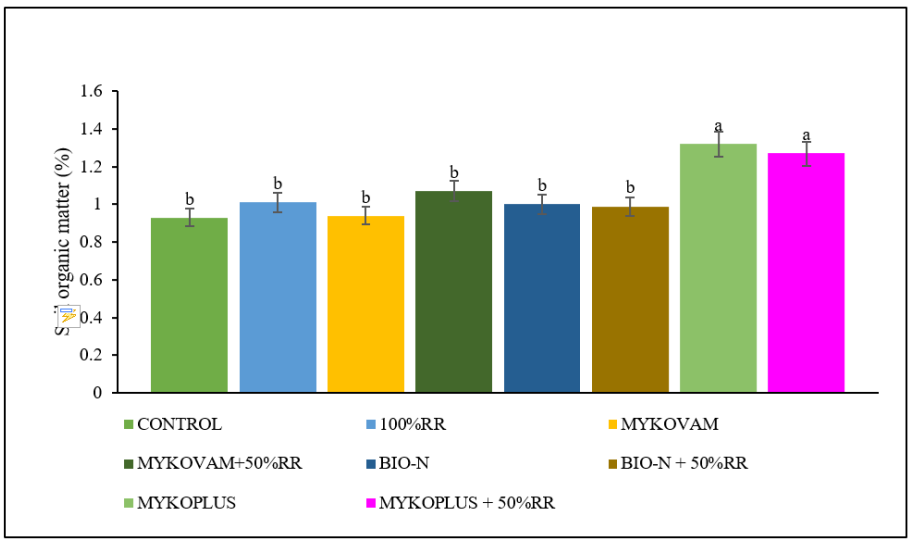


Figure 4. Soil organic matter (%) of *Hibiscus surattensis* applied with different bioinoculants. Means followed by the same letter within each soil type are not significantly different at $p \leq 0.05$ based on Tukey's HSD test. Error bars represent ± standard error of the mean

Total Nitrogen (%)

Nitrogen of *H. surattensis* grown in different soil types applied with different bioinoculants is presented in Figure 5 & 6. The results indicated that both soil type and bioinoculant treatment significantly influenced soil nitrogen levels. The highest mean nitrogen content was observed in neutral soil (0.0743%), while the lowest was recorded in acidic soil (0.0328%). Regarding bioinoculant applications, the highest total nitrogen content was observed in soils treated with Mykoplus and Mykoplus + 50% RR, with mean values of 0.0661% and 0.0638%, respectively. The lowest total nitrogen was recorded in the control treatment (0.0466%), although this value was comparable to those of other bioinoculant treatments. Analysis of variance (ANOVA) further revealed no significant interaction between soil type and bioinoculant application on the total nitrogen content of soil planted with *H. surattensis*. The observed increase in soil nitrogen with bioinoculant applications aligns with studies showing that microbial inoculants can enhance soil nitrogen by improving nitrogen fixation, nutrient cycling, and rhizosphere microbial activity.

Singh et al. (2022) demonstrated that bioinoculants, particularly those containing plant growth-promoting rhizobacteria (PGPR), significantly increased soil nitrogen concentrations in various cropping systems. This increase is attributed to the ability of PGPR strains to fix atmospheric nitrogen and make it available for plant uptake, thereby improving soil fertility (Aloo et al., 2022).

Furthermore, biofertilizers containing nitrogen-fixing bacteria have been shown to improve soil nitrogen levels by promoting biological nitrogen fixation and reducing the reliance on synthetic fertilizers (Simarmata, 2023). The absence of a significant interaction effect in this study suggests that, while bioinoculants influence soil nitrogen levels, soil type may play a less critical role in this interaction than the microbial treatments themselves.

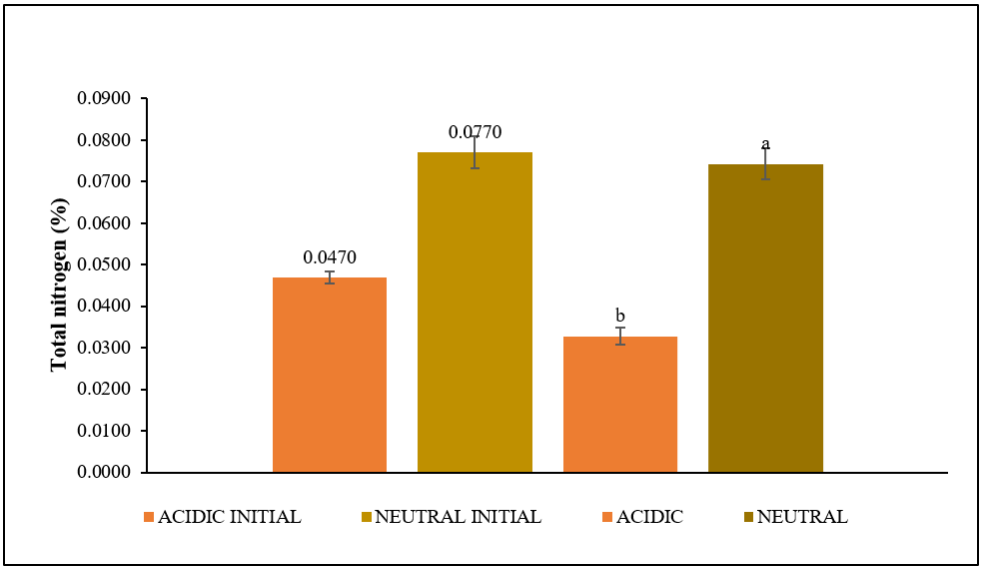


Figure 5. Total nitrogen (%) of *Hibiscus surattensis* grown in different soil types. Means followed by the same letter within each soil type are not significantly different at $p \leq 0.05$ based on Tukey's HSD test. Error bars represent ± standard error of the mean

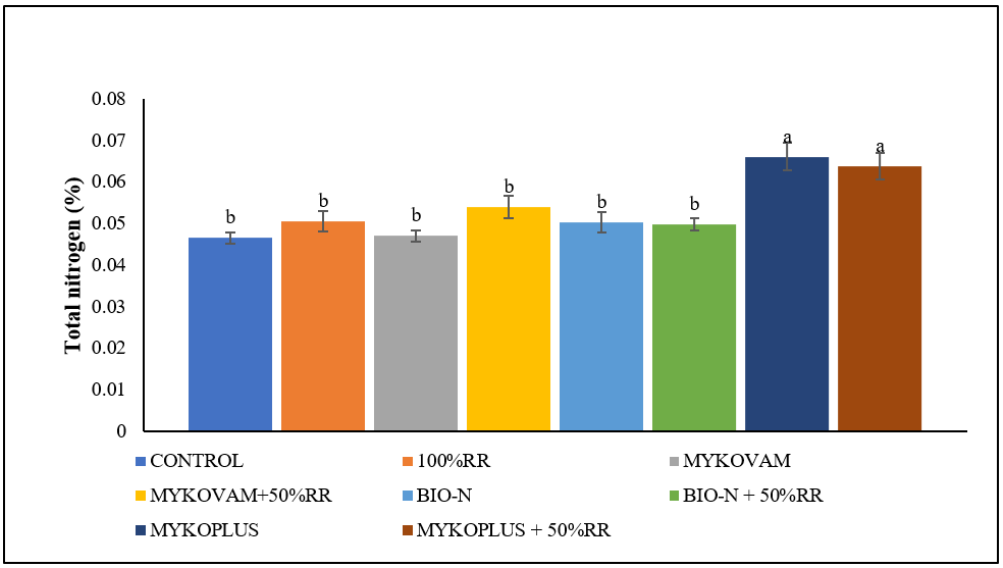


Figure 6. Total nitrogen (%) of *Hibiscus surattensis* applied with different bioinoculants. Means followed by the same letter within each soil type are not significantly different at $p \leq 0.05$ based on Tukey's HSD test. Error bars represent ± standard error of the mean.

Available P (ppm)

Figure 7 presents the available phosphorus content of soil planted with *H. surattensis*. The results indicated that both soil type and bioinoculant application significantly influenced soil available phosphorus, and ANOVA further revealed a significant interaction between the two factors.

The highest phosphorus level was recorded in plants grown in neutral soil applied with 100% RR fertilizer, with a mean of 83.25 ppm, comparable to plants applied with Bio-N + 50%RR, suggesting that the combination of favorable soil conditions and optimal fertilizer application enhances phosphorus availability for plant uptake. In contrast, the lowest phosphorus content was observed in acidic soil without bioinoculant application (0.20 ppm), likely due to reduced phosphorus solubility at low pH. Phosphorus-solubilizing bacteria and fungi are capable of converting insoluble forms of phosphorus into plant-available phosphate ions through organic acid production, enzymatic mineralization, and chelation mechanisms (Pan et al., 2023; Silva et al., 2023).

This microbial activity is especially important under acidic soil conditions where phosphorus tends to form insoluble complexes with iron and aluminum, limiting plant access; inoculation with PSMs can mitigate this limitation by increasing phosphorus solubility (Iftikhar et al., 2024). Additionally, biofertilizer applications that combine phosphorus solubilizers with conventional fertilizers have been shown to enhance soil phosphorus availability and support soil nutrient cycling, supporting the concept that the combination of favorable soil conditions and appropriate amendments increases phosphorus accessibility for plant roots (Fitriatin, 2021).

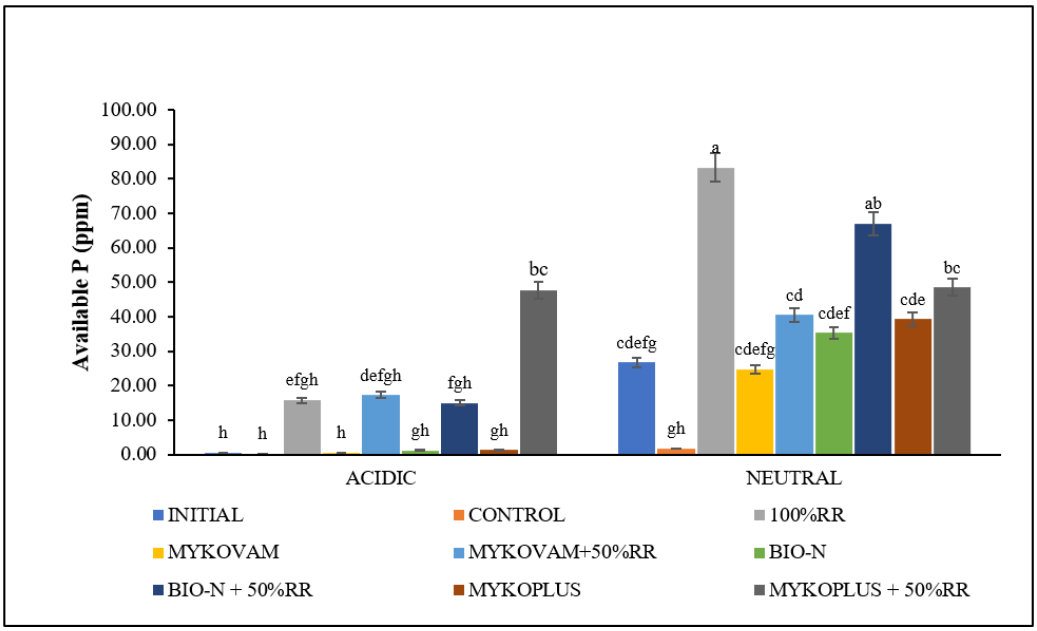


Figure 7. Interaction effect of soil type and, bioinoculants application on available P (ppm) of *Hibiscus surattensis* soils. Means followed by the same letter within each soil type are not significantly different at $p \leq 0.05$ based on Tukey's HSD test. Error bars represent ± standard error of the mean

Exchangeable Bases K (ppm)

Data on the exchangeable bases (K) are presented in Figure 8 & 9. Soils with neutral pH consistently exhibited higher exchangeable potassium (K) concentrations compared to acidic soils, both initially (neutral: 700.15 ppm; acidic: 430.25 ppm) and at the end of the experiment (neutral: 660.66 ppm; acidic: 310.41 ppm). This pattern aligns with broader soil chemistry dynamics, in which soil pH influences the capacity of clay minerals and organic matter to retain cations such as K^+ on exchange sites and to reduce their leaching losses (Mazahar and Umar, 2024). In acidified soils, high concentrations of hydrogen (H^+) and aluminum (Al^{3+}) ions compete with K^+ for cation exchange sites, reducing the soil's ability to hold and supply potassium to plants (Mazahar and Umar, 2024).

Regarding bioinoculant applications, the highest exchangeable K was observed in soils receiving the 100% recommended rate (RR) fertilizer (858.75 ppm), while the lowest was in the uninoculated control (255.62 ppm). These differences may be due to the fertilization effect on overall soil fertility, which enhances K inputs and potentially stimulates microbial processes that influence nutrient cycles. Although no significant interaction between soil type and bioinoculant was detected in the ANOVA, research suggests that soil microorganisms, particularly potassium-solubilizing microorganisms (KSMs), can improve the availability of otherwise fixed K by solubilizing potassium-bearing minerals into forms accessible for plant uptake (Mazahar and Umar, 2024). KSMs achieve this through mechanisms such as the secretion of organic acids and chelating agents that mobilize K from mineral matrices, thereby enhancing the soil K pool (Mazahar and Umar, 2024). Taken together, these findings support the notion that soil chemical properties and management practices play pivotal roles in regulating exchangeable K status in cropping systems. Neutral soil conditions generally favor greater exchangeable K retention, while bioinoculants and appropriate fertilization can augment the nutrient supply necessary for optimal plant growth.

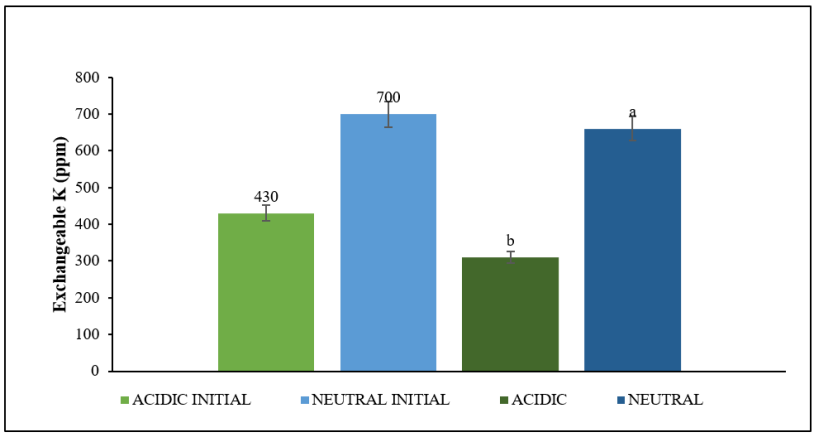


Figure 8. Exchangeable K (ppm) of *Hibiscus surattensis* grown in different soil types. Means followed by the same letter within each soil type are not significantly different at $p \leq 0.05$ based on Tukey's HSD test. Error bars represent ± standard error of the mean

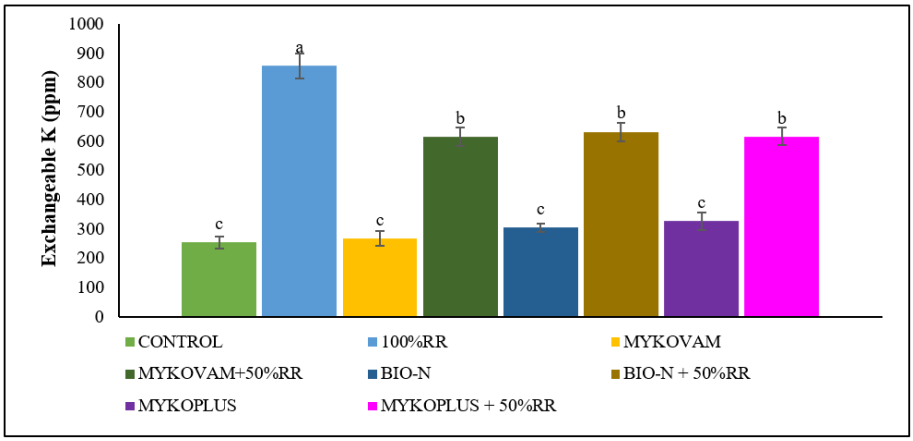


Figure 9. Exchangeable K (ppm) of *Hibiscus surattensis* applied with different bioinoculants. Means followed by the same letter within each soil type are not significantly different at $p \leq 0.05$ based on Tukey's HSD test. Error bars represent ± standard error of the mean

CONCLUSION

The application of bioinoculants had a significant impact on the soil fertility dynamics of *Hibiscus surattensis* across different soil types. Among the bioinoculant treatments tested, Mykoplus demonstrated the greatest enhancement of soil fertility, indicating its potential as an effective soil amendment for this species. It is recommended to conduct further studies under similar conditions to validate these findings and assess the consistency and accuracy of the results. Additionally, exploring the long-term effects of Mykoplus on soil health and plant growth would provide valuable insights for sustainable cultivation of *Hibiscus surattensis*.

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